Space Weather Technical Forecast

Issued on Wednesday, 03 January 2024 at 13:29 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Further M-flares likely from AR3536 with a slight chance of X-flares.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Moderate with one M-flare observed, peaking at M1.1 at 02/1830 UTC from AR3536 in the northeast. This continues to be the main region of note and although the main spot has split into two smaller spots of opposing polarity, a small delta spot is apparent. Furthermore there remains a number of small spots of varying polarities following this main spot. There are a total of five sunspot regions on the disc, with the other four all smaller and simpler.

A number of CMEs were visible in imagery, however these have all been assessed as being off the Earth-Sun line with no Earth-directed CMEs occurring.

Solar Wind / Geomagnetic Activity: Solar winds were indicative of a weak fast wind from CH86/-, followed by the more recent arrival of a CME, likely from the X5.0 flare that left the sun on 31 Dec. Speeds varied between 380-450km/s for much of the period, but increased abruptly to peak at 466km/s at 03/0456 UTC. Since then speeds have steadily declined to around 420km/s. Density was largely at, or below below average, but increased to above average levels with the arrival of the CME, peaking at 18ppcc at 03/0536 UTC, before returning to average levels by the end of the period. Interplanetary Magnetic Field (IMF), Bt, initially varied between weak and moderate levels (5-8nT), but increased to peak 12nT at 03/0517 UTC, before declining to weak levels following this. The north-south component, Bz varied weakly between northward and southward directions at first, but reached moderately positive levels briefly, following the CME arrival, then became predominantly weakly negative. Phi angle was generally negative (towards the Sun). Geomagnetic activity was Quiet to Unsettled (Kp1-3).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux is at background levels, but on an increasing trend, with the >10MeV Proton flux close to the S1/Minor Storm threshold at time of issue. GOES16 high energy (greater than 2MeV) electron flux ranged was mainly at background. The 24-hour fluence was below Active throughout. The 03/0000 UTC observation was 1.31e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Region AR3536 in the northeast dominates the flare risk during the forecast period. Generally Moderate activity is expected, with further M-flares likely and a slight chance of further X-flares.

Solar Wind / Geomagnetic Activity: The CME from the X5.0 flare on 31 Dec appears to have given Earth a minor glancing impact early on 03 Jan, with minimal geomagnetic effects observed. There is a chance for one or two weak CMEs to arrive at Earth between day 1 and early day 2 (03-04 Jan), but these are low confidence to occur and would likely only result in very minor geomagnetic effects. Current fast winds from CH86 are expected to continue days 1-2 (03-04 Jan), before easing to background days 3-4 (05-06 Jan). No other enhancements are forecast. Quiet geomagnetic activity is expected for much of the period, with a decreasing chance of isolated Unsettled intervals. Any CME influence on day 1 or 2 (03-04 Jan) will bring a

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slight chance of Active intervals.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux has risen close to the S1/Minor Storm threshold in response to recent significant flare activity. There is a chance of exceeding S1 storm levels on day 1 and 2 (03-04 Jan), then a slight chance on subsequent days, dependent on any further notable flares occurring. GOES16 high energy electron flux is likely to remain near background, perhaps briefly rising to Moderate later in the period, with the associated fluence remaining below the Active level.

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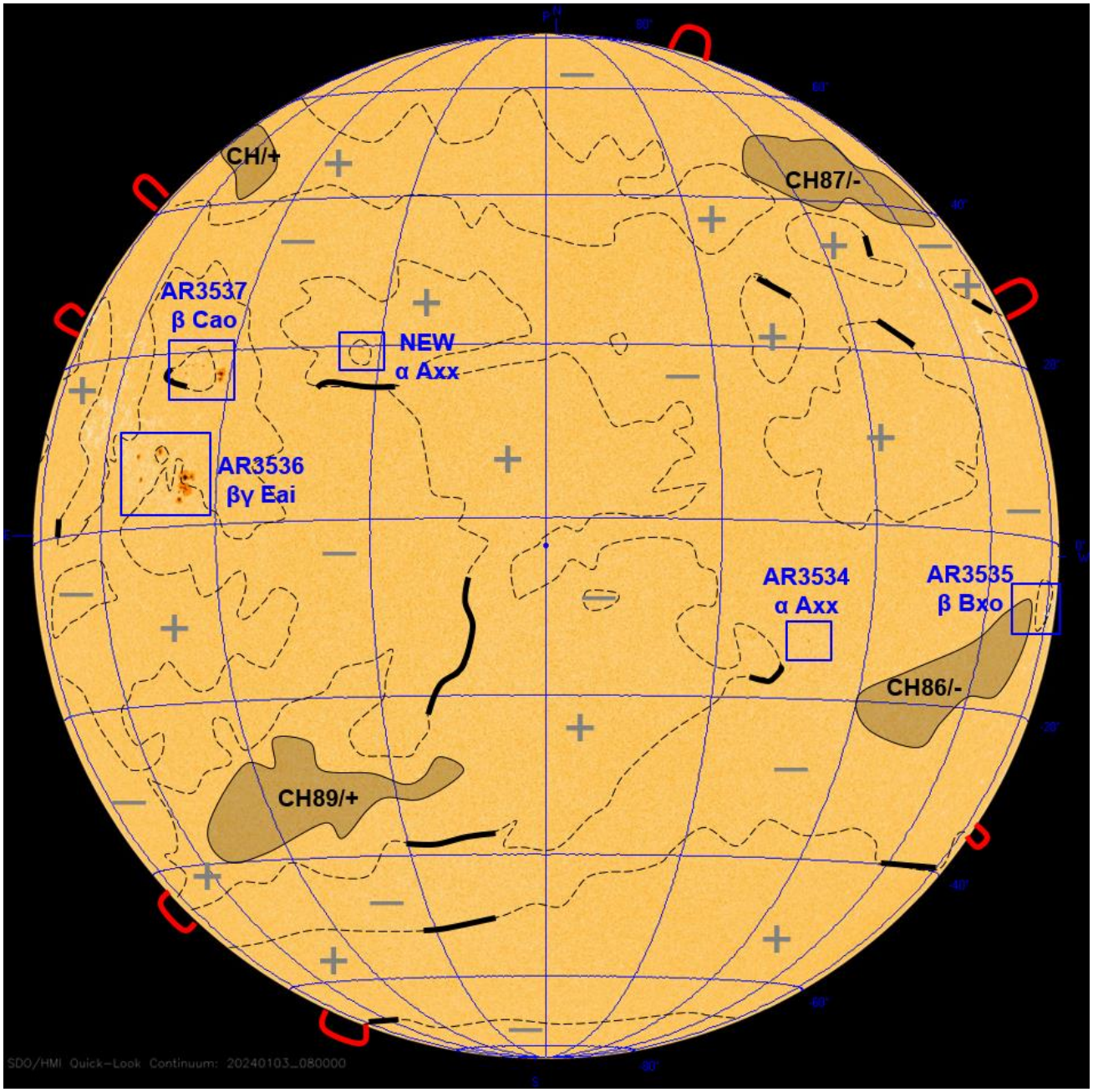
Figure 1. Solar Analysis Valid 03/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

The CME from the X5.0 flare on 31 Dec appears to have given Earth a minor glancing impact early on 03 Jan, with minimal geomagnetic effects observed.

There remains a chance for a couple of weak CMEs to have influence on the observed solar wind at Earth through day 1 and into early day 2 (03-04 Jan), including a slow C-flare on 30 Dec and a filament eruption off the northwest disc on 31 Dec. These are all low confidence however, and would likely result in only slight enhancements above the ongoing, but weakening fast wind from CH86/-.

Otherwise, fast winds from CH86/-, with speeds 400-450km/s are expected to continue day 1 and day 2 (03-04 Jan). No other solar wind enhancements are then expected, with the fast wind expected to gradually ease towards background days 3 and 4 (05-06 Jan).

Quiet geomagnetic activity is expected for much of the period, with a decreasing chance of isolated Unsettled intervals. Any CME influence on day 1 or 2 (03-04 Jan) will bring a slight chance of Active intervals.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	1	1	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
30/2000	Nil	C2.6 AR3534	SE	320 km/s	03 – early 04 Jan	Likely miss. Slight glance possible
31/1433	Nil	Filament	NW	907 km/s	03 – early 04 Jan	Likely miss. Slight glance possible

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Radio Blackouts - X-Ray Flares:

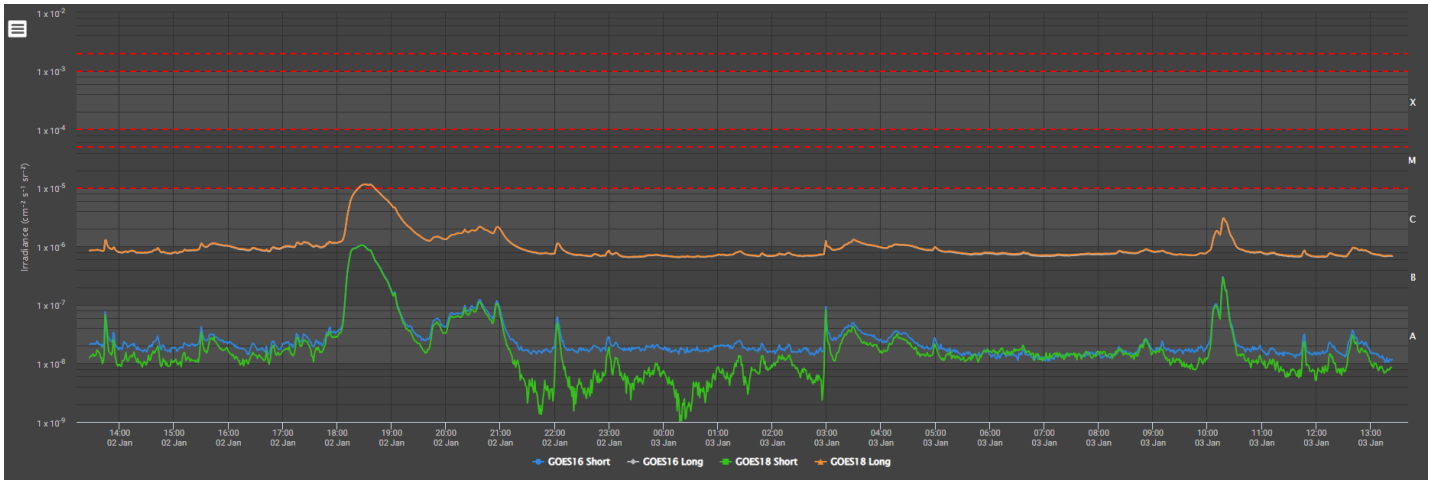
Moderate activity is expected to continue with further M-flares likely from AR3536 and a slight chance of X-class flares.

There are five sunspot regions on the disc, four numbered and one unnumbered. AR3536 in the northeast remains the main sunspot of interest. This region produced an X5.0 flare on 31 Dec, and a number of smaller M-class flares since. Although the main spot has split into two smaller spots of opposing polarity, they remain in close proximity to one another with a small delta spot apparent within the more southerly of the two. Furthermore there remain a number of small spots of varying polarities following this main spot and some bright looping evident within its magnetic canopy on SDO imagery. This means that despite the relatively small and ragged appearance of the spot, there remains a likely risk of M-flares, and a slight chance of further X-flares from this region.

The other regions are mainly smaller and simpler, with AR3534 now largely decayed, and AR3535 soon rotating off the west limb. AR3537 in the northeast appears stable at this time. The newly emerged, unnumbered region in the northeast is developing a number of small spots of mixed polarity and will be monitored for any further growth.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	55	55	55	55
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 2: GOES-16/18 X-ray flux



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Solar Radiation Storms - (High Energy Protons):

GOES16 high energy (greater than 10MeV) proton flux is at background levels, but on an increasing trend, with the >10MeV Proton flux close to the S1/Minor Storm threshold at time of issue. This is the result of the recent large flares from AR3536. There is a chance of exceeding the S1/Minor Storm threshold on day 1 and 2 (03-04 Jan). Any further significant flares, primarily from this region, will bring a risk of further increases in the observed proton flux. This gives a slight chance of reaching the S1 Minor Storm level from day 3 (05 Jan) onwards, perhaps slightly increasing on day 4 (06 Dec) as the region moves further west on the disc and into a more central location.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	40	20	5	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) as observed by GOES-16 continues to persist at mostly background levels. The fast wind arrival on 02 Jan was weaker than originally expected, with only minimal geomagnetic activity observed. Furthermore, no significant CME enhancements have been observed. There are further weak CME arrivals possible on day 1-2 (03-04 Jan) however these are unlikely to significantly impact the forecast. Consequently, mainly background flux is expected to continue with a chance of reaching Moderate during periods of diurnal maximum.

The associated 24 hour fluence is forecast to persist at background, although a rising trend is likely day 3-4 (05-06 Jan), as solar winds ease. This is supported by REFM which is currently giving good guidance.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	1	1
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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Figure 3: GOES16 >2MeV Electron Flux and MOSWOC REFM with recurrence

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